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Deltaic Sedimentation in Glacial Lake Douglas

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ABSTRACT

A lobate sand body extends into the basin of glacial Lake Douglas from a gap in both the Pesotum and West Ridge Moraines in east-central Illinois. Textural analyses indicate the sand body is composed of four distinct sands that can be distinguished on the basis of their sand:silt:clay ratios, mean grain size, and sorting. Underlying the sands are fine-grained sediments that can be classified into three units—sandy silt, clayey silt, and silty clay.

The sands probably were deposited as a delta built into Lake Douglas. The lower sediments may represent an initial period of fluvial deposition, and the overlying sands may represent successive periods of deltaic progradation interrupted by periods of nondeposition or erosion.

INTRODUCTION

Many deltas, deposited in either pluvial or glacial Pleistocene lakes, have been reported (Gilbert, 1890; Upham, 1895; Chapman, 1937; Happ, 1938; Jahns and Willard, 1942a, 1942b; Bretz, 1950; Koteff, 1963; Eschman and Farrand, 1970; Hansen and Kume, 1970). The deltas have been extensively used to determine Pleistocene lake levels, degree of postglacial rebound, and glacial drainage patterns. For the most part, descriptions of the deltas have been concerned with the morphology of the deposits and semiquantitative estimations of grain size. In a few studies, however, the mineralogy and textures of Pleistocene lake deltas have been examined to differentiate the deltas from other features produced during glaciation (Krynine, 1937; Epstein, 1969).

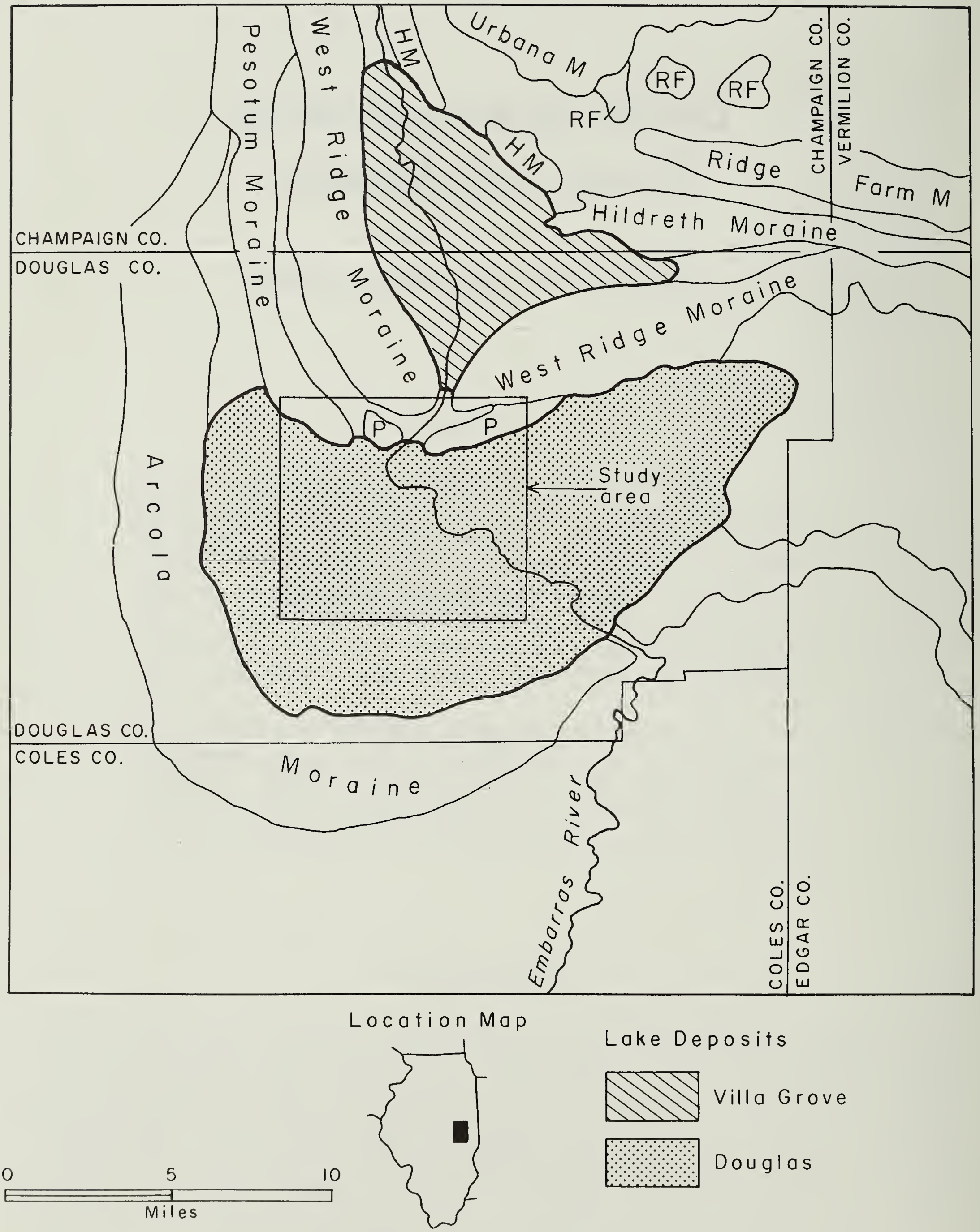

Fig. 1 - Regional relations of the study area, including the moraines and the postulated areal extent of glacial Lake Douglas (Willman and Frye, 1970) and glacial Lake Villa Grove.

During the course of an investigation of the soils developed on sediments deposited in glacial Lake Douglas, Gardiner, Odell, and Hallbick (1966) encountered clean, fairly well sorted sands in a lobate structure that extended from a gap in both the West Ridge and Pesotum Moraines in Douglas County, Illinois. They suggested that these sands might represent deltaic sediments. Our preliminary study of the morphology of the landform showed that it differed from the outwash deposits along the moraines in that its upper surface coincided with the maximum elevation Gardiner and co-workers had postulated for the water level in the lake on the basis of the topography of the lake basin and the maximum elevation of the fine-grained lake sediments.

To determine whether this structure did, indeed, represent a delta built into Lake Douglas, we conducted a sampling program for which 46 hand-auger holes were drilled and 225 samples collected. Sand:silt:clay ratios were calculated for all samples, and a determination of the grain-size distribution was made on all samples containing more that 40 percent sand. In addition, X-ray diffraction analyses of the less than 2-micron fraction of all samples were conducted.

In this report we use those data to (1) determine whether or not the sand body was a delta; (2) determine what pattern of deposition would occur with a retreating sediment source and a fluctuating base level; and (3) reconstruct the history of glacial Lake Douglas.

REGIONAL SETTING

Glacial Lake Douglas lay in Douglas County in east-central Illinois (fig. 1). The lake formed in a basin between the Arcola Moraine to the south and the West Ridge and Pesotum Moraines to the north and was filled by the glacial Embarras River, which entered the basin through a gap in the two northern moraines. The gap occurred over a preglacial bedrock valley of the Mahomet Valley System (Horberg, 1950). The sides of the gap slope gradually from the crest of the moraine at a gradient of about 10 feet per mile to the 660-foot elevation, where the present Embarras River has incised its valley to below 630 feet.

The Arcola and West Ridge Moraines do not meet to the east, leaving a gap trending east-west between them. Maximum elevation in the gap is between 655 and 660 feet along a rise trending north-south that now acts as a drainage divide. Streams to the west of the rise enter the Embarras River and those to the east enter the Vermilion River system, indicating that the gap did not serve as an outlet for lake drainage.

Another gap occurs in the Arcola Moraine to the south. The sides of this gap slope uniformly down to 650 feet, at which point the gradient increases abruptly to the bottom of the river valley at 610 feet. The Embarras cuts a southeast-trending valley through the moraine and then turns abruptly south.

Lake Douglas was about 30 miles long and 8 miles wide, and had a total area of 120 square miles (Gardiner, Odell, and Hallbick, 1966). The present topographic expression of the former lake basin is a nearly level, poorly drained plain with a general elevation of 640 feet. Near the margin of the lake the land rises gradually to the 650-foot elevation and then more steeply onto the moraines surrounding the basin.

In the area of the delta, the topography under the sand shows a fairly uniform gradient sloping south to the 635-foot level. Here the gradient decreases

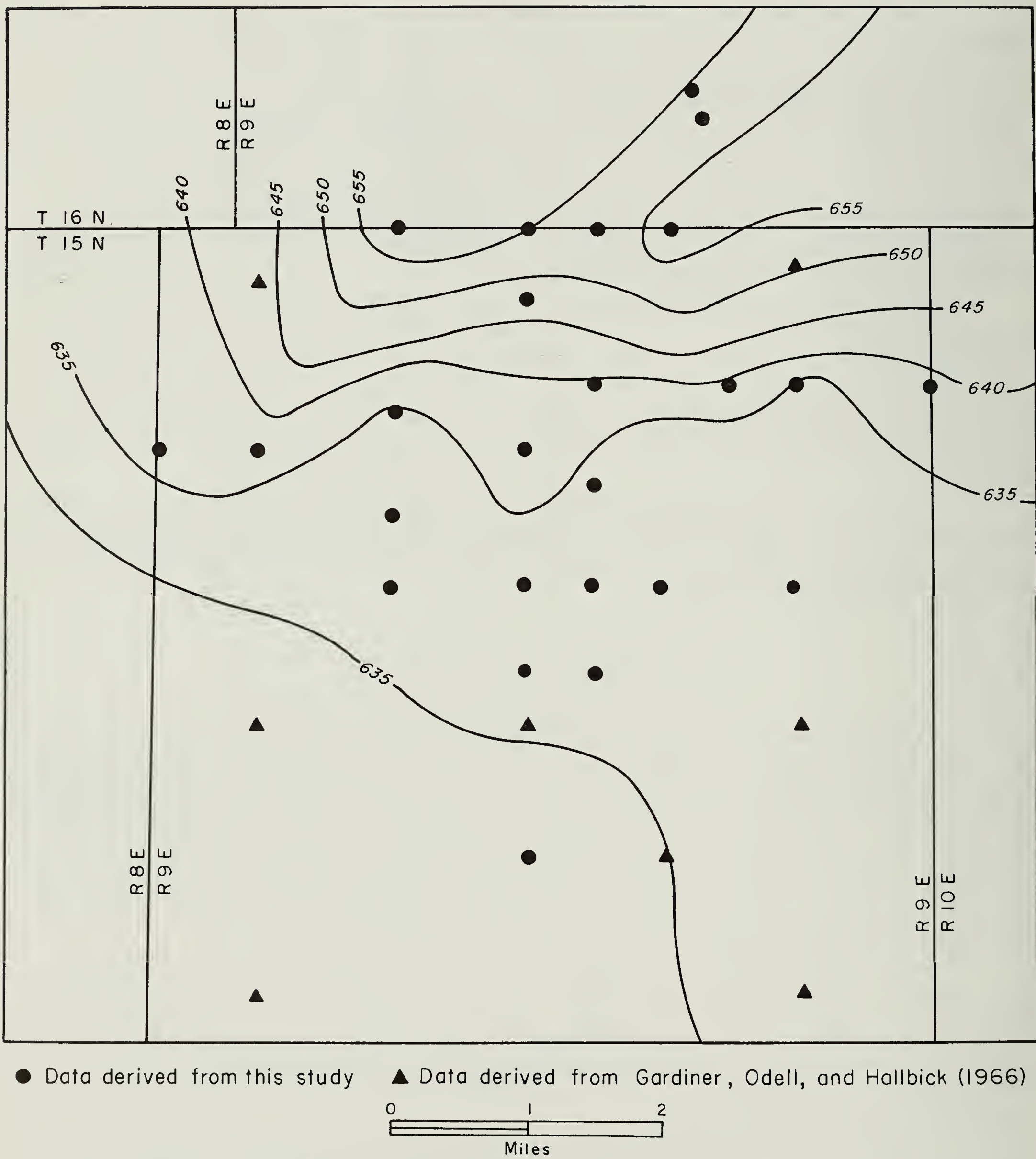

Fig. 2 - Topography of the surface underlying the sand body, excluding the effects of Holocene erosion.

near the margin of the lake basin and begins to slope southeastward toward the central area of the lake (fig. 2).

To the north of Lake Douglas, a roughly triangular basin exists between the West Ridge Moraine to the south and west and the Hildreth Moraine to the north. Although this basin was not included by Gardiner, Odell, and Hallbick (1966) in their description of lake sediments, preliminary drilling during our study indicates that it, too, held a lake that trapped sediments. This glacial lake is here named Lake Villa Grove.

Glacial lake sediments of Illinois have been stratigraphically assigned by Willman and Frye (1970) to the Equality Formation. The formation includes the Carmi Member, consisting of fine-grained silt and clay, and the Dolton Member, consisting of coarser grained sand and gravel.

MORPHOLOGY AND ANALYSES OF TEXTURE

The Lake Douglas sand body is lobate in plan view. It is about 6 miles across east to west and 4 miles across north to south (fig. 3). It is prismatic in

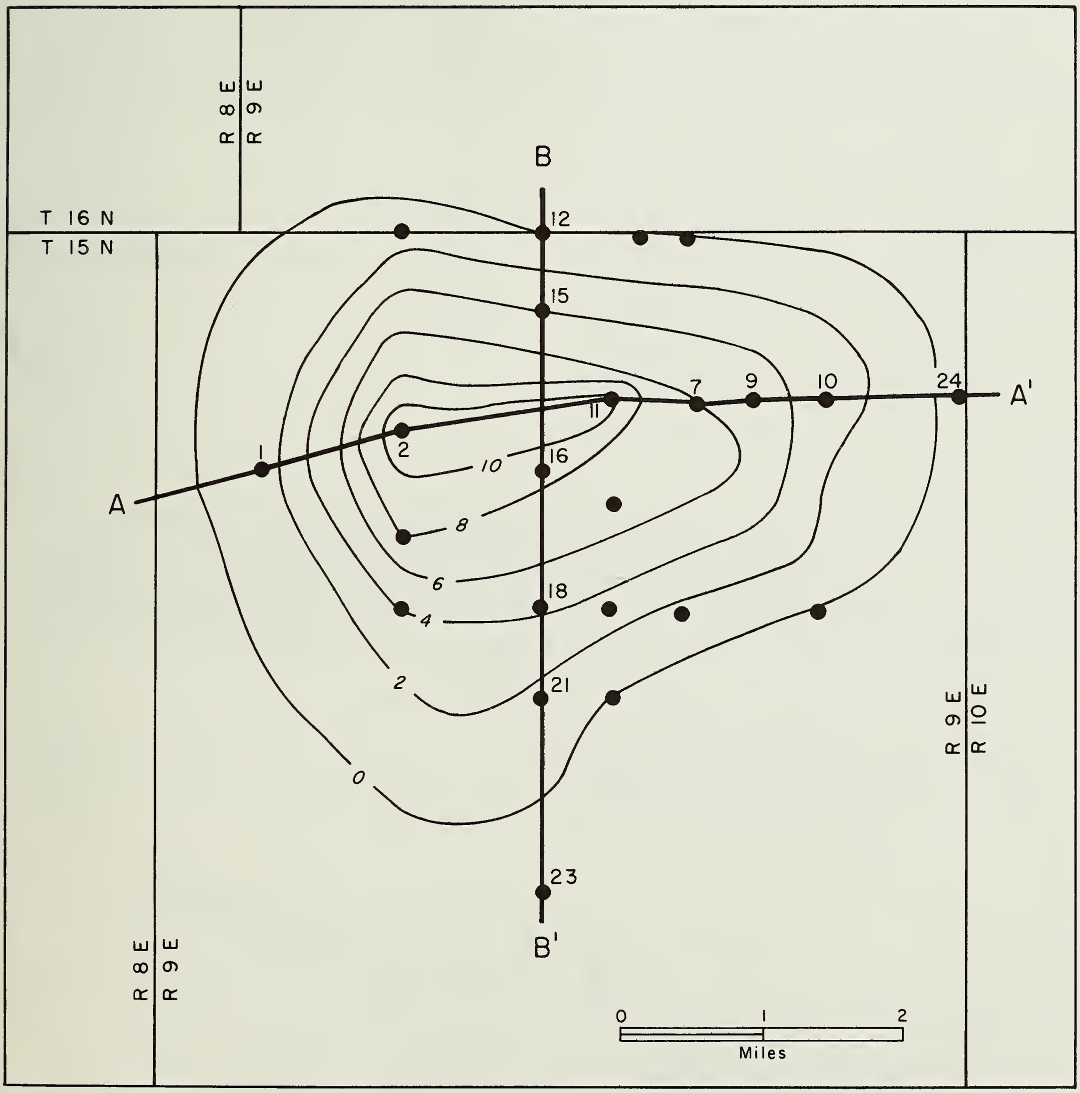

Fig. 3 - Isopach map of the sand body, excluding the effects of Holocene erosion and deposition.

cross section and reaches its maximum thickness at the slope break in the lake bottom where more than 10 feet of sand has accumulated. The upper surface of the sand body slopes southward from the moraine at a gradually decreasing gradient.

Textural analyses of the deposits associated with the delta indicated that the sediments could be divided into seven main groups based on sand:silt: clay ratios, mean grain size, and sorting (as measured by the standard deviation of the grain-size distribution) (table 1).

TABLE 1 — AVERAGE TEXTURAL CHARACTERISTICS

Material	Sand (%)	Silt (%)	Clay (%)	Mean size (ϕ)	Sorting (ϕ)
Loess-derived	15.9	53.0	31.1		
Sand IV	56.0	24.4	19.6	4.94	3.43
Sand III	70.4	16.0	14.3	3.41	3.56
Sand II	81.6	9.6	9.5	1.92	3.13
Sand I	90.3	5.4	4.8	0.88	2.34
Clay-silt A	1.9	48.0	50.2		
Clay-silt B	5.8	74.2	20.1		
Clay-silt C	17.1	65.0	17.8		
Till	28.5	39.8	32.2		

Although the textures of the loess-derived material and the coarse-grained clay-silt C deposits are somewhat similar, they can easily be differentiated by clay mineral analysis. The clay minerals of the clay-silt deposits consist of illite and chlorite and are mineralogically similar to those of the underlying till. The clay minerals of the loess, on the other hand, are illite and substantial amounts of expandable clay minerals.

The sand:silt:clay ratios of the loessial material average 16:53:31, but the ratios are extremely variable. Where colluviation has taken place or where clay has been transported downward during pedogenesis, any of the constituents could have been enriched or depleted, depending upon slope position and depth of leaching. The ratios of the till, on the other hand, do not vary significantly from the average of 29:40:32.

The fine-grained sediments in the vicinity of the delta can be broken down into three units. Group A may be considered the normal lake deposit in Lake Douglas; it corresponds to the clayey sediment described by Gardiner, Odell, and Hallbick (1966). Silt and clay predominate in this group, occurring in approximately equal amounts, averaging 48 and 50 percent, respectively. The amount of sand is generally less than 5 percent. Groups B and C are somewhat coarser grained and correspond to the silty sediment in Gardiner, Odell, and Hallbick's classification. Both B and C are characterized by high silt contents, but C contains more sand than B.

Clay-silt C deposits are found in front of the gap in the West Ridge and Pesotum Moraines. On either side of the gap, as well as downslope into the

lake basin, these sediments grade into the finer grained clay-silt A and B deposits (fig. 4). Near the moraine, clay-silt B and C deposits rest on till, but farther from the moraine they overlie clay-silt A sediments.

Sand I is the lowest sand deposit of the delta (fig. 4). Most samples contain more than 90 percent sand that is relatively coarse grained. The lower part of Sand I in front of the gap in the moraines and along a line extending south from it is especially coarse, consisting of up to 30 percent pebbles and fine gravel. On either side of this line the sand is somewhat finer grained. Near the moraine, Sand I is deposited on till, but southward from the moraine it is deposited on clay-silt C and, still farther south, on A and B deposits. The contact between Sand I and these underlying materials is very sharp.

Sand II is finer grained and more poorly sorted than Sand I. Because the water content of the sand was very high it was impossible to take undisturbed cores with the available equipment. The contact between Sands I and II, therefore, was never observed, and it could never be absolutely determined whether

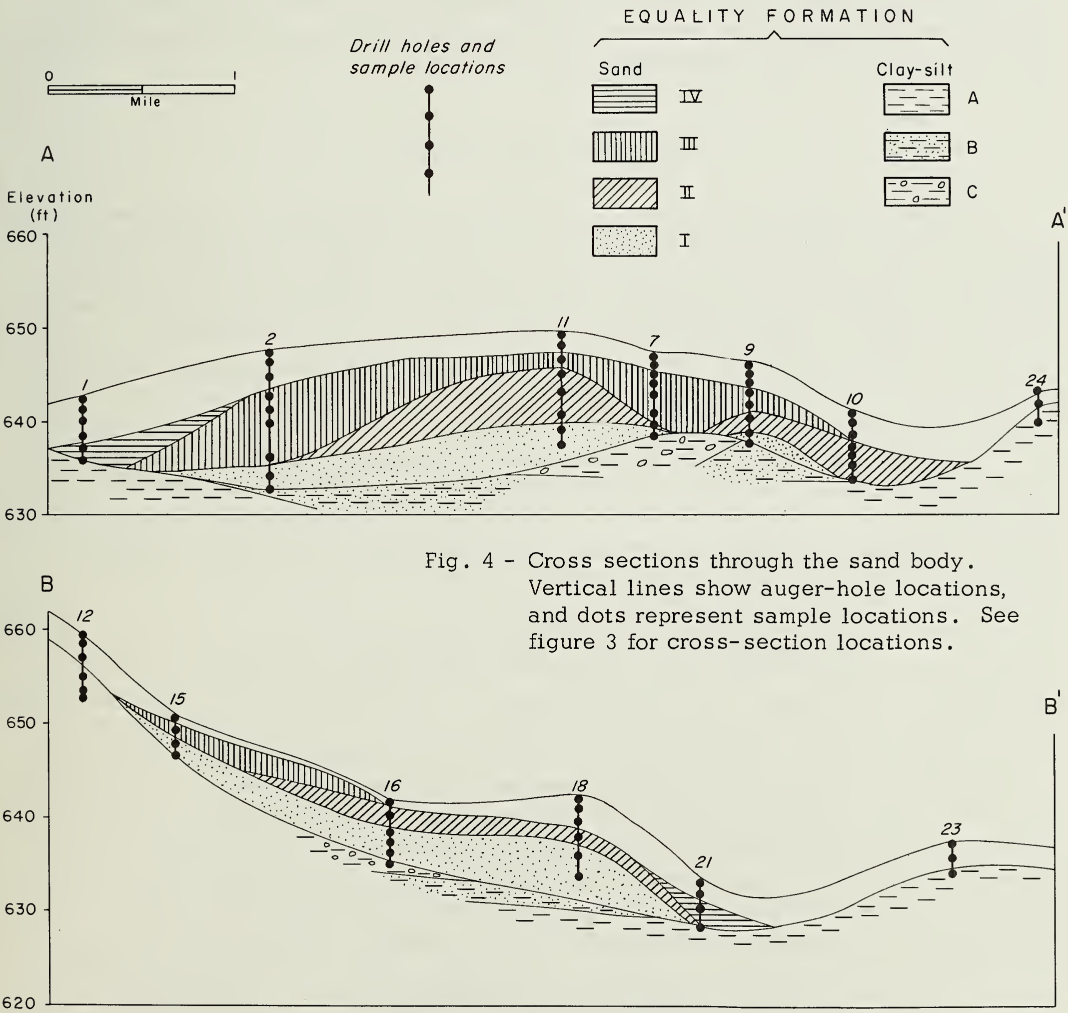

Fig. 4 - Cross sections through the sand body. Vertical lines show auger-hole locations, and dots represent sample locations. See figure 3 for cross-section locations.

the textural change between the two sediments was abrupt or gradational. Most samples were taken at 1.5-foot intervals, and the change in texture from I to II was abrupt within this interval. In addition, some samples were taken at 0.5-foot intervals, and the abrupt textural change between the two sands still occurred.

East-west cross sections drawn through the sand body show that Sand II was either deposited in two pods or was subtly channeled after deposition (fig. 4). Continuity of textural characteristics and lateral homogeneity of the sediments indicate that Sand II was deposited as a single body and gently eroded after deposition.

Sand III blankets all earlier sand deposits near the moraines, but apparently was not deposited near the southern margin of the sand body. The difference in texture between Sand II and Sand III is abrupt, Sand III being very much finer grained, not as well sorted, and having significantly lower sand percentages.

Sand IV is very fine grained and poorly sorted. Sand percentages average about 56 percent, and clay mineral analyses indicate mixing of sand and the overlying silty loess. The position of Sand IV at the bottom of marginal slopes around the sand body indicates that it is probably a colluviated material derived from the underlying sand and mixed with loess.

DEPOSITIONAL HISTORY

After the formation of the Arcola Moraine, the glacial ice withdrew to the position of the Pesotum and West Ridge Moraines. There is a possibility that standing water existed between the Arcola Moraine and the retreating ice front. If it had, the bottommost sediments of Lake Douglas would include the coarser sands and gravels deposited directly in front of the ice as it retreated. Gardiner, Odell, and Hallbick (1966), however, showed that the sands in Lake Douglas are found, for the most part, on the margins of the basin and are related to the enclosing moraines.

If there had been water standing in the Lake Douglas basin when the ice front reached the position of the West Ridge Moraine, the delta would have begun to prograde into the lake immediately after the construction of the moraine had begun. Simple progradation, however, does not explain the abrupt change in texture between the lower and upper parts of Sand I or the change from Sand I to Sand II.

It is more probable that Lake Douglas did not form during the retreat of the ice front. In the first place, it has been shown that, because of englacial and subglacial drainage, an ice front might not necessarily act as a dam (Sissons, 1958, 1960; Embleton, 1964; Embleton and King, 1969). Second, if there had been standing water in Lake Douglas when the ice finally reached the position of the northern moraines, the delta would have been built against the ice. The delta, however, displays none of the features commonly associated with the ice contact (kame) deltas that were described by Embleton and King (1969). Third, the initial deposits in the basin in front of the gap in the moraine appear to be fluvial in origin. Here are found the coarsest clay-silt C deposits (up to 30 percent sand and 60 percent silt) as well as the coarsest of the Sand I deposits (up to 30 percent fine gravel). In addition, Gardiner, Odell, and Hallbick (1966) found silty sediment with interfingering sand stringers in four drill holes in the vicinity of the delta. These deposits are characteristic of braided drainage from

melting glaciers caused by a sudden decrease of capacity in sediment-laden streams as the gradient abruptly decreases. The streams deposit their coarse material and spread out to form the wide, shallow channels of sandurs (outwash plains) (Embleton and King, 1969).

Instead of accumulating between the ice and the Arcola Moraine, the water from the retreating glacier may have escaped, either through drainage channels now covered by lake sediments or as subglacial drainage. In the latter case the formation of the lake would have been dependent on the formation of the West Ridge and Pesotum Moraines as the northern dam of the lake.

Once drainage was established through the gap in the moraines, fluvial deposits were laid down on the floor of the Lake Douglas basin. Coarse material was deposited near the moraine where the stream gradient rapidly decreased, and progressively finer material was carried basinward by a braided stream. This pattern would be interrupted locally, wherever more competent currents in the shifting channels of the braided stream might carry sand out onto silts and clays, forming isolated sand stringers.

As the water level of the lake began to rise, it eventually reached the point at which the bulk of the sands and gravels were being deposited and deposition of the truly deltaic sediments of the upper part of Sand I was begun. Although the delta had been in a constructional phase during the rise in lake level, it probably was not prograding during that period. The rising water level resulted in a transgressive pattern of sedimentation, with finer sediments deposited over coarser ones as the point of origin of the stream-flow into the lake retreated northward. As the rise in water level diminished, the delta began to prograde lakeward, depositing a sequence of coarser materials over finer sediments.

The abruptness of the change from Sand I to Sand II represents a period of nondeposition between the time of deposition of Sand I and the time when Sand II began to prograde into the lake. Although the current entering the lake may not have been competent enough to transport sand, it may have been able to carry much of the silt and clay beyond the southern margin of the delta. This would explain the lack of fine-grained material at the contact between Sands I and II.

As the ice front retreated to the position of the Urbana and Hildreth Moraines, the northern triangular basin was exposed. It was probably during this period that Sand II was subtly channeled.

The erosion could have been accomplished in two ways. The Villa Grove basin could simply have acted as a sediment trap for sand-sized material, causing a cessation of deposition on the delta and resulting in subaqueous erosion. On the other hand, if the lake level had been lowered during a period of reduced discharge of water through the gap in the northern moraines, subaerial erosion could have occurred.

Water discharge into Lake Douglas could have been reduced during the period that the Villa Grove basin was being filled or during a rearrangement of drainage patterns when the structurally complex Urbana and Hildreth Moraines were formed. Reduced water discharge would probably have resulted in the lowering of the water level of Lake Douglas, permitting subaerial erosion to occur immediately after flow through the gap was reestablished. The stream may again have taken the form of braided drainage with a wide, shallow channel.

This period ended as the Villa Grove basin filled with coarse-grained material,and sand was once again available to permit progradation of the delta as Sand III was deposited. This material was much finer grained than Sands I and II because of the greater distance of the source of the material from the site of

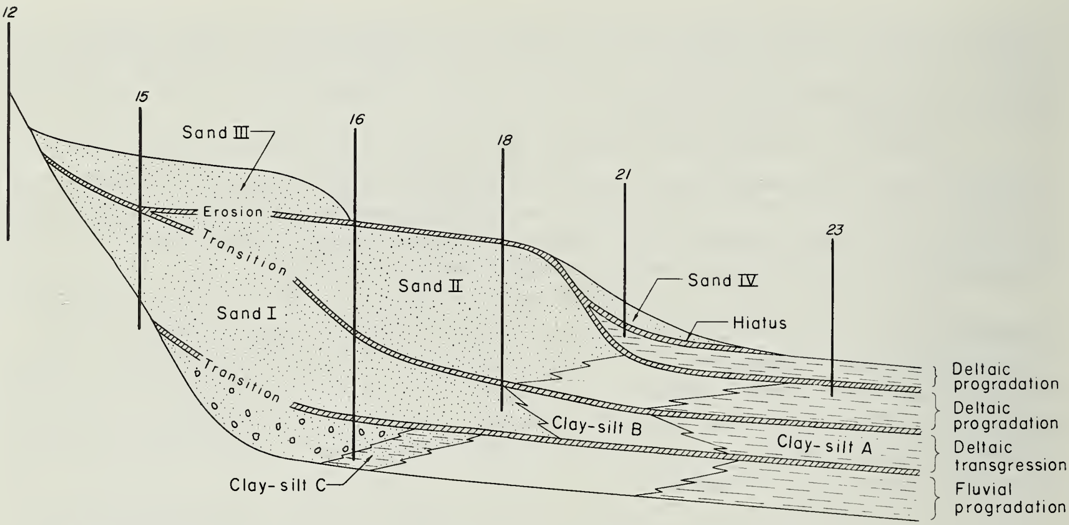

Fig. 5 - Diagrammatic north-south cross section through the sand body showing the facies development. The sediments correspond to those shown in figure 4.

deposition. The abrupt contact between Sand III and the earlier deposits was, again, due to a period of nondeposition during which the northern basin acted as a sediment trap.

Lake Douglas drained as the Embarras River cut through the gap in the Arcola Moraine. As the lake level dropped, the Embarras shifted westward in a wide bend as it sought lower ground around the lobate form of the delta (fig. 1). Sand IV, loess, and loess-derived material were probably deposited contemporaneously. Pedogenesis and colluviation resulted in the various textures seen in the vicinity of the sand body.

DISCUSSION

A diagrammatic representation of the facies development in the glacial Lake Douglas delta appears in figure 5. The vertical lines represent the auger holes shown in figure 4 and demonstrate the correspondence of the facies to the sediments that actually occur in the sand body.

Fluvial progradation resulted in the deposition of coarser sediments over finer ones until rising water caused deposition of a transgressional deltaic sequence of finer over coarser sediments. The surface between progradation and transgression was a transitional one.

Delta construction continued during transgression with the delta building "backwards" as the point of flow of the current into the lake retreated toward the moraine. As the lake water reached its maximum level, the delta began to prograde onto the earlier deposits. The surface between this phase and the earlier constructional phase is also one of transition. A period of nondeposition and erosion occurred as the glacial ice withdrew to the position of the Urbana and Hildreth Moraines, and an erosional surface was produced on Sand II. Sand III was deposited on this surface during a period of deltaic progradation after Lake Villa Grove filled with sediment.

Explanations for the presence of the sand body in glacial Lake Douglas other than a combination of fluvial and deltaic deposition probably can be devised. We feel, however, that the hypothesis outlined above furnishes the best explanation of the following characteristics of the delta:

1) The morphology that is lobate in plan view and prismatic in cross section, with the upper surface coincident with the postulated upper surface of the water level of Lake Douglas.
2) The presence of coarse-grained material at the base of the body.
3) The abrupt contact between Sands I and II and between Sands II and III.
4) The channeling in Sand II.
5) The lateral variations in texture of the fine-grained deposits.
6) The wide bend in the Embarras River after it emerges from the gap in the West Ridge Moraine.

REFERENCES

Bretz, J H., 1950, Glacial Lake Merrimac: Illinois Acad. Sci. Trans., v. 43, p. 132-136.

Chapman, D. H., 1937, Late-glacial and postglacial history of the Champlain Valley: Am. Jour. Science, 5th ser., v. 34, no. 200, p. 89-124.

Embleton, Clifford, 1964, Sub-glacial drainage and supposed ice-dammed lakes in northeast Wales: Geologists' Assoc., v. 74, p. 31-38.

Embleton, Clifford, and C. A. M. King, 1969, Glacial and periglacial geomorphology: Edward Arnold, London, 608 p.

Epstein, J. B., 1969, Surficial geology of the Stroudsburg Quadrangle, Pennsylvania-New Jersey: Pennsylvania Geol. Survey Bull. G 57, 67 p.

Eschman, D. F., and W. R. Farrand, 1970, Glacial history of the glacial Grand Valley: Geol. Soc. America Guidebook, North-Central Section, p. 131-141.

Gardiner, M. J., R. T. Odell, and D. C. Hallbick, 1966, Poorly drained soils and geomorphology of glacial Lake Douglas in Illinois: Jour. Geology, v. 74, no. 3, p. 332-343.

Gilbert, G. K., 1890, Lake Bonneville: U. S. Geol. Survey Mon. 1, 438 p.

Hansen, D. E., and Jack Kume, 1970, Geology and ground-water resources of Grand Forks County, Part I: Geology: North Dakota Geol. Survey Bull. 53, 76 p.

Happ, S. C., 1938, Significance of Pleistocene deltas in the Minisink Valley: Am. Jour. Science, 5th ser., v. 36, no. 216, p. 417-439.

Horberg, C. L., 1950, Bedrock topography of Illinois: Illinois Geol. Survey Bull. 73, 111 p.

Jahns, R. H., and M. E. Willard, 1942a, Late Pleistocene and recent deposits in the Connecticut Valley, Massachusetts, Part I: Am. Jour. Science, v. 240, no. 3, p. 161-191.

Jahns, R. H., and M. E. Willard, 1942b, Late Pleistocene and recent deposits in the Connecticut Valley, Massachusetts, Part II: Am. Jour. Science, v. 240, no. 4, p. 265-287.

Koteff, Carl, 1963, Glacial lakes near Concord, Massachusetts: U. S. Geol. Survey Prof. Paper 475-C, p. 142-144.

Krynine, P. D., 1937, Glacial sedimentology of the Quinnipiac Pequabuck Lowland in southern Connecticut: Am. Jour. Science, 5th ser., v. 33, no. 194, p. 111-139.

Sissons, J. B., 1958, Supposed ice-dammed lakes in Britain with particular reference to the Eddleston valley, southern Scotland: Geografiska Annaler, v. 40, p. 159-187.

Sissons, J. B., 1960, Subglacial, marginal, and other glacial drainage in the Syracuse-Oneida area, New York: Geol. Soc. America Bull., v. 71, p. 1575-1588.

Upham, Warren, 1895, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 645 p.

Willman, H. B., and J. C. Frye, 1970, Pleistocene stratigraphy of Illinois: Illinois Geol. Survey Bull. 94, 204 p.

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